N94-23612

GAF-14-057

5th Earth Observing System Investigator Working Group
Calibration & Data Product Validation Panel

Apr. 7-9,1992 at Broker Inn

ASTER TIR Subsystem & Calibration

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FUJITSU LIMITED

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Outline

1. Purpose of TIR
2. Major functions
3. Characteristics and design of various components
4. Calibration

C-5

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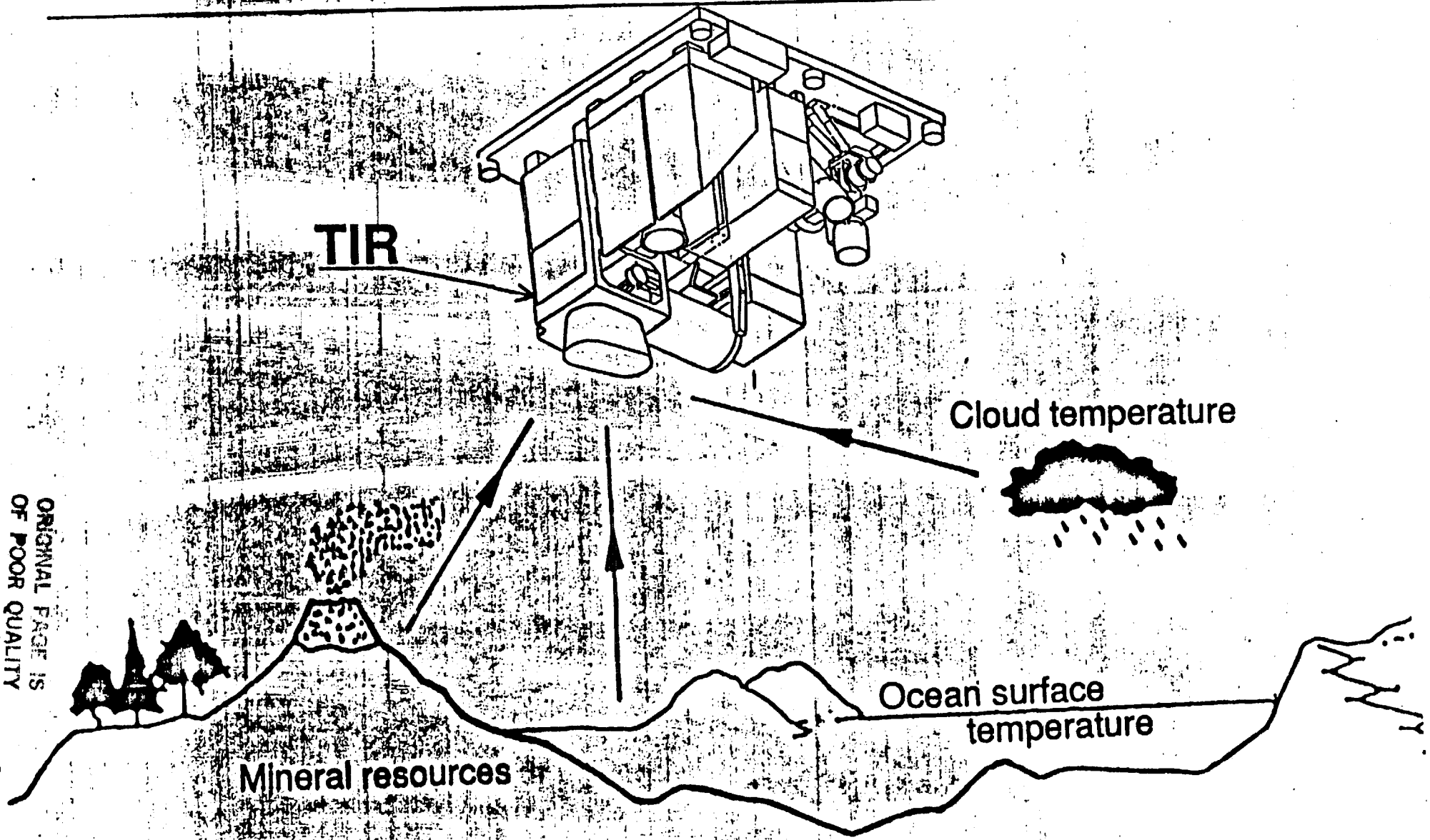

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Functions

-to acquire image data on the earth's surface in thermal infrared wavelength band, using mercury cadmium telluride (HgCdTe) detectors, the detectors are cooled about 80K

-to convert the obtained image data into the digital data to meet the Common Signal Processer(CSP) interface, and output the signals

-pointing function in cross-track direction to get the wide swath of 232km

-to calibrate the whole TIR with the blackbody on orbit, then the amplifer and subsequent transmission units are calibrated electrically

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TIR General Specifications

Spectral coverage	Band10	8.125 to 8.475 µm
	Band11	8.475 to 8.825 µm
	Band12	8.925 to 9.275 µm
	Band13	10.25 to 10.95 µm
	Band14	10.95 to 11.65 µm
Swath width		60 km
Geometric Resolution		90 m
IFOV		127.6 µrad
MTF at Nyquist freq		0.25
Signal Quantization level		12bit
Pointing Coverage		± 8.55 deg
Radiometric resolution		NEΔT: < 0.3 K

Cutaway view of the TIR

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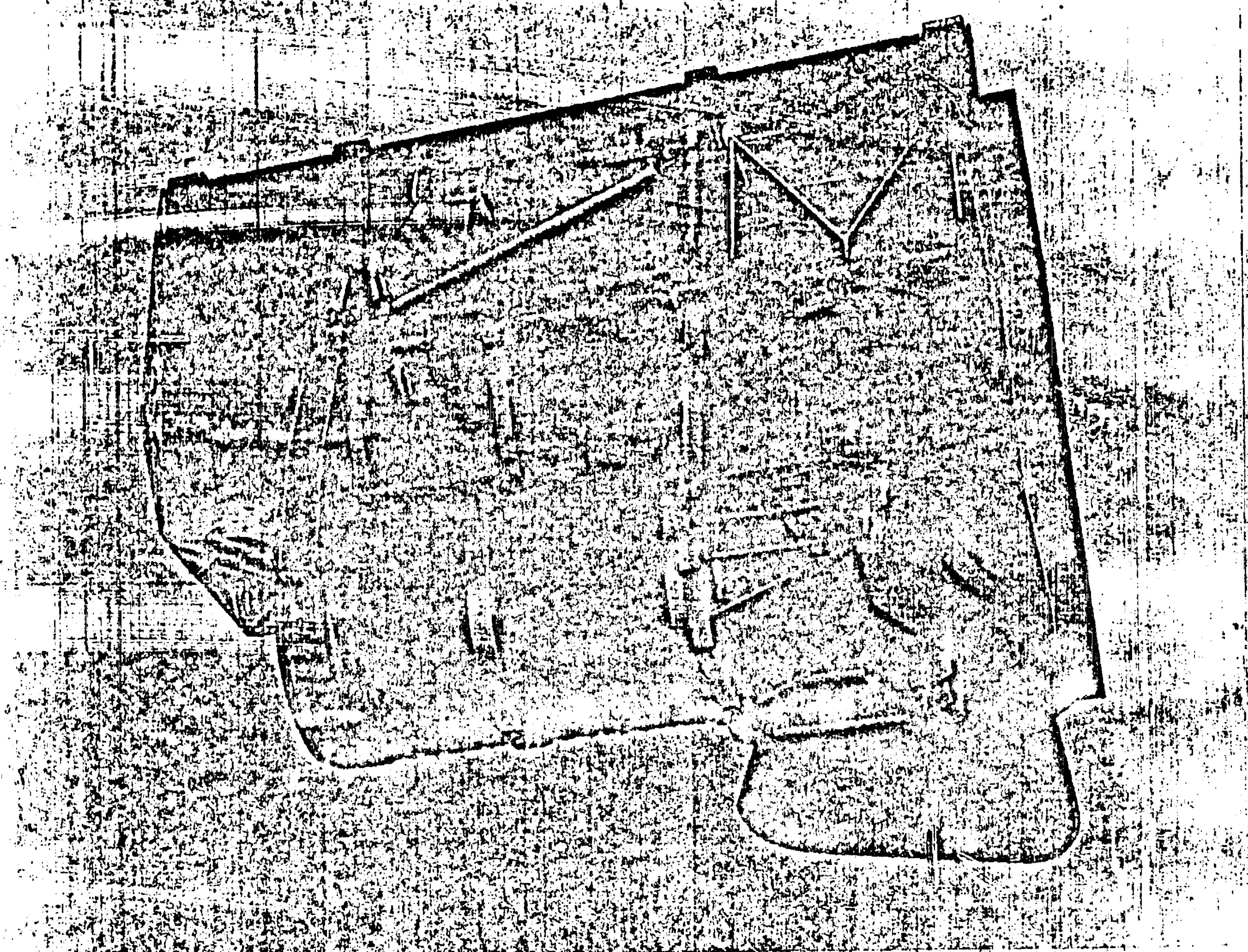

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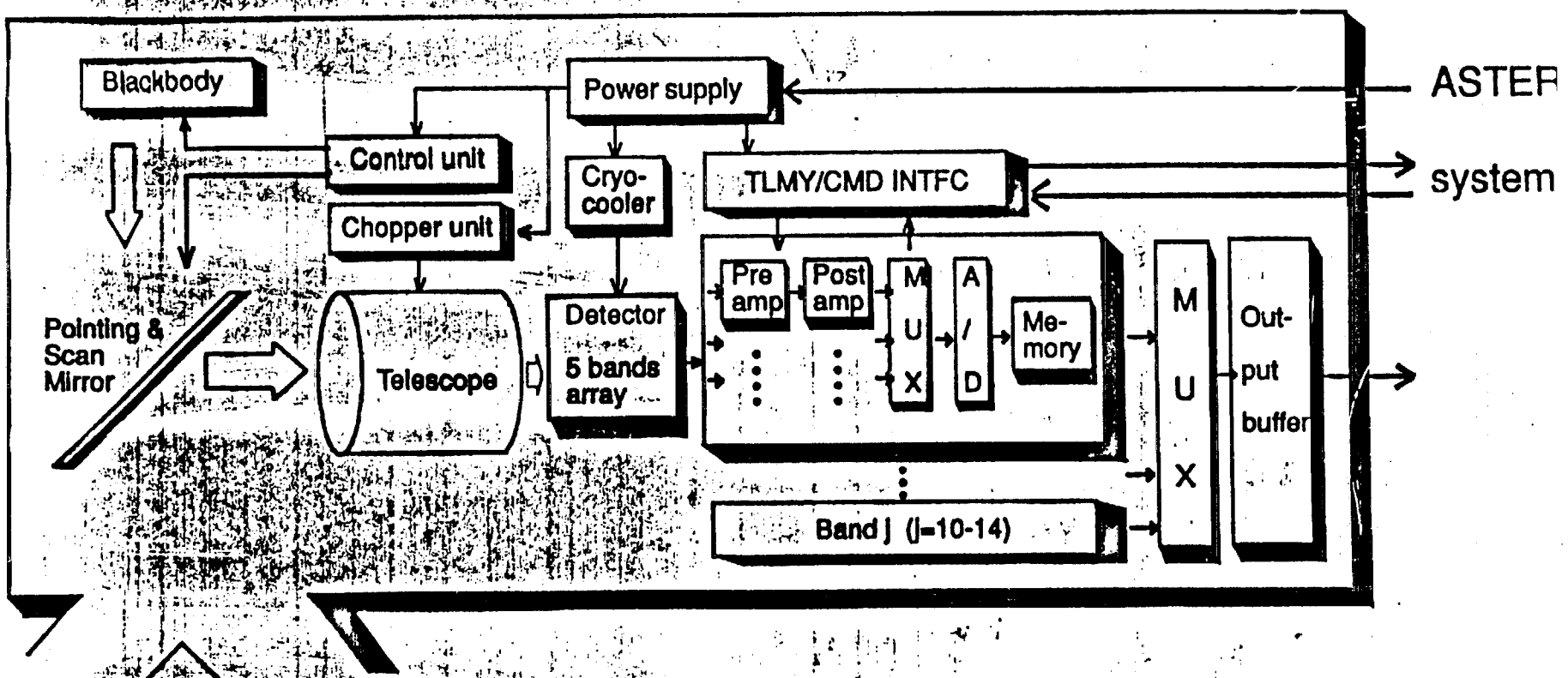
TIR block diagram



Thermal emission from the earth

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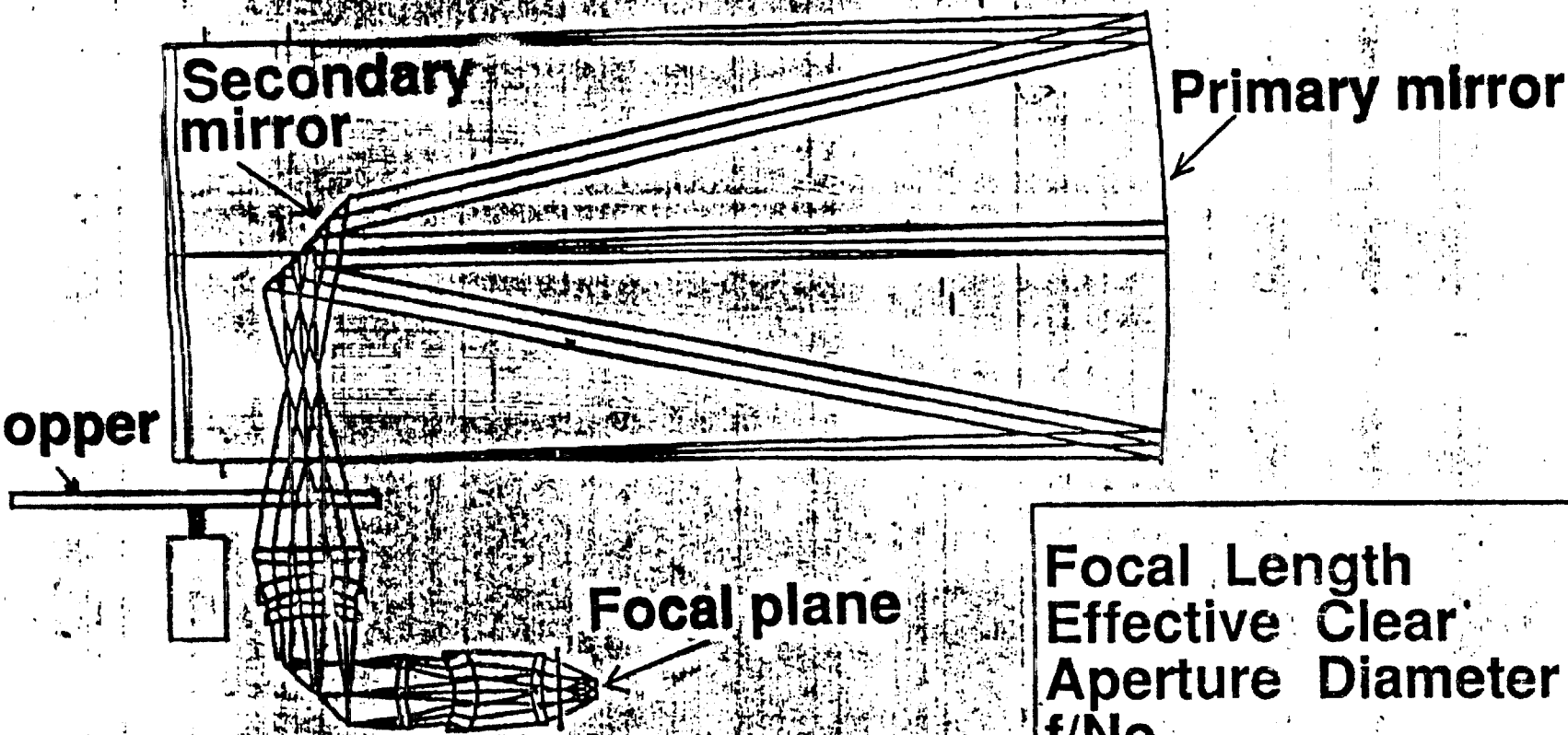
Telescope



Focal Length	392 mr
Effective Clear Aperture Diameter	240 mr
f/No	1.57
FOV	1.67 de

Newtonian Catadioptric

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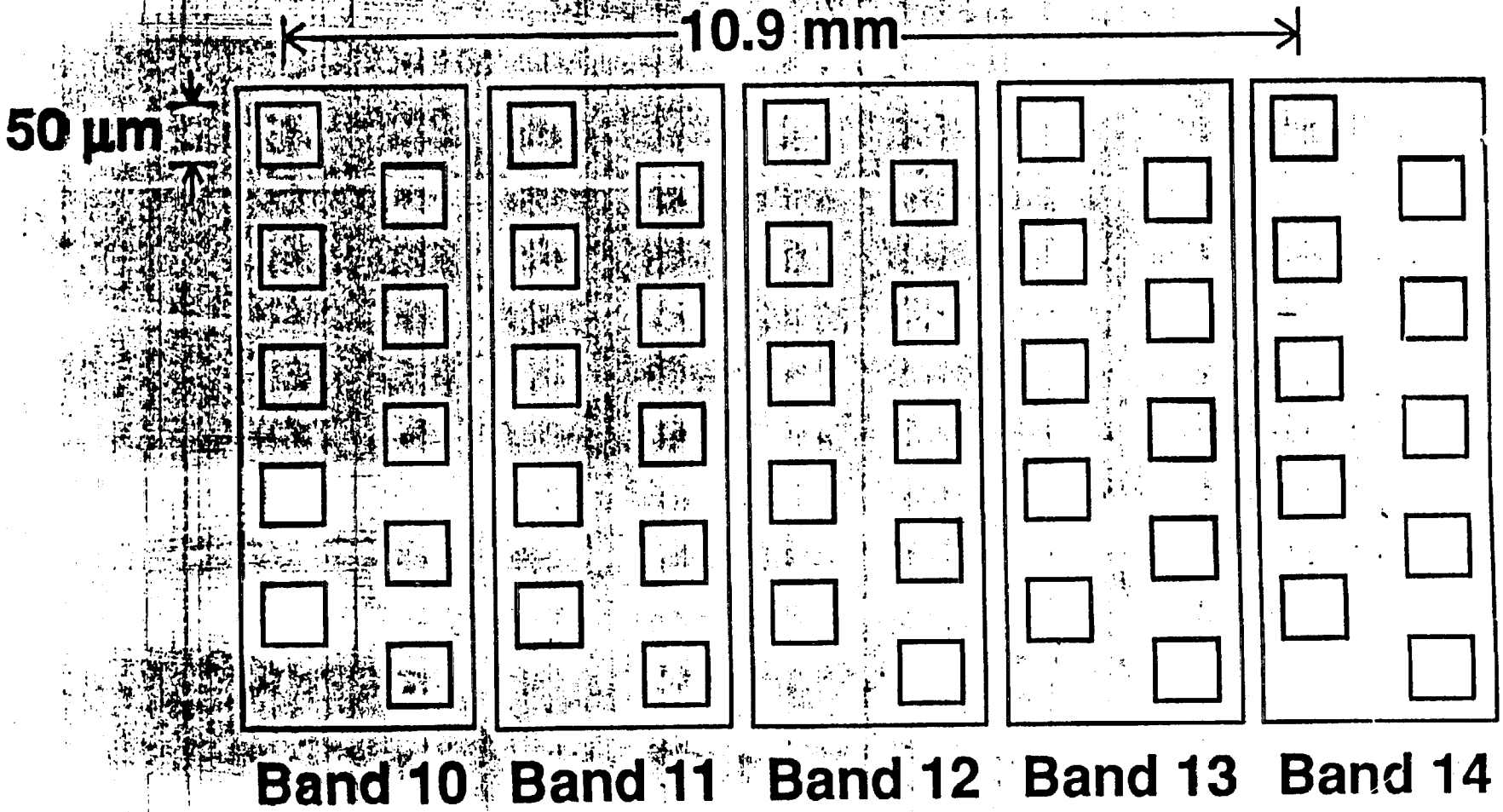
HgCdTe Detectors



Focal plane projection

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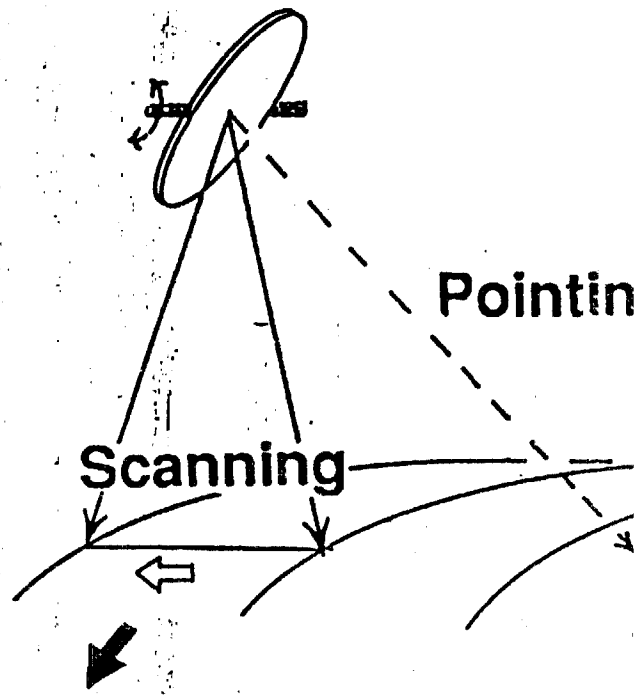
Scanner

Pointing and Scanning	
Scanning method	Mechanical scan by vibration of scan mirror ± 3.4deg (at pointing center)
Pointing(off-nadir)	scan mirror ± 8.55 deg (off-nadir angle)
Mirror size	460mm X 280mm
Mirror material	Beryllium



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Callbration Accuracy Requirement

200 K to 240 K	3K
240 K to 270 K	2K
270 K to 340 K	1K
340K to 370 K	2K

Calibration methods

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Pre-launch calibration

- TIR acceptance test(AT) ---> calibration data map ---> characteristics equation of TIR and data set of calibration

- Cross calibration with other EOS-AM1 sensors

Calibration methods

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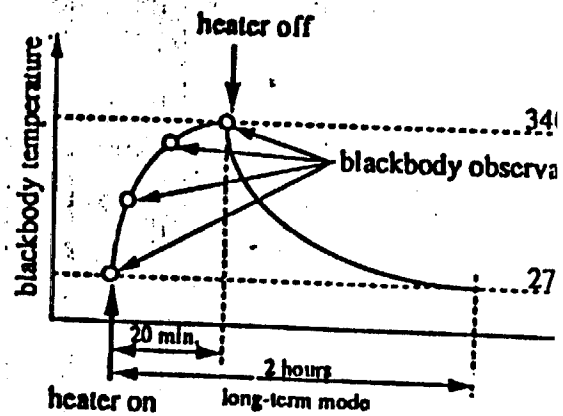
In-flight calibration

calibration methods

calibration	mode	input
optical calibration	short-term calibration	blackbody radiation
	long-term calibration	blackbody radiation
electrical calibration	electrical calibration	step electric signals

calibration data

mode	blackbody temperature	calibration time
short-term calibration	270K	several ten seconds
long-term calibration	270K - 340K 3-temperature:270K 300K 340K or more temperature	20 minutes approx. (observation of blackbody) 2 hours approx. (heat-up & cool-down)



Calibration methods

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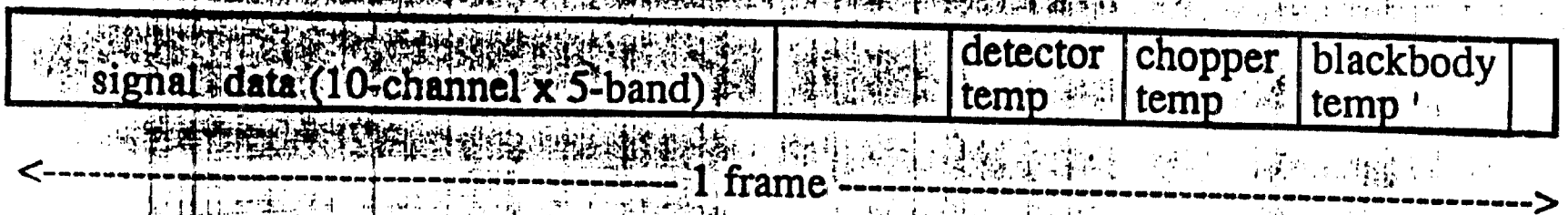
Usable data for calibration

(1) Image data
- digitized signal data(blackbody radiation) :same as observation data
- blackbody temperature :inserted signal data
- chopper temperature :ditto
- detector temperature :ditto



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Calibration methods

Usable data for calibration

(2) Monitor data/ telemetry data

TIR temperature

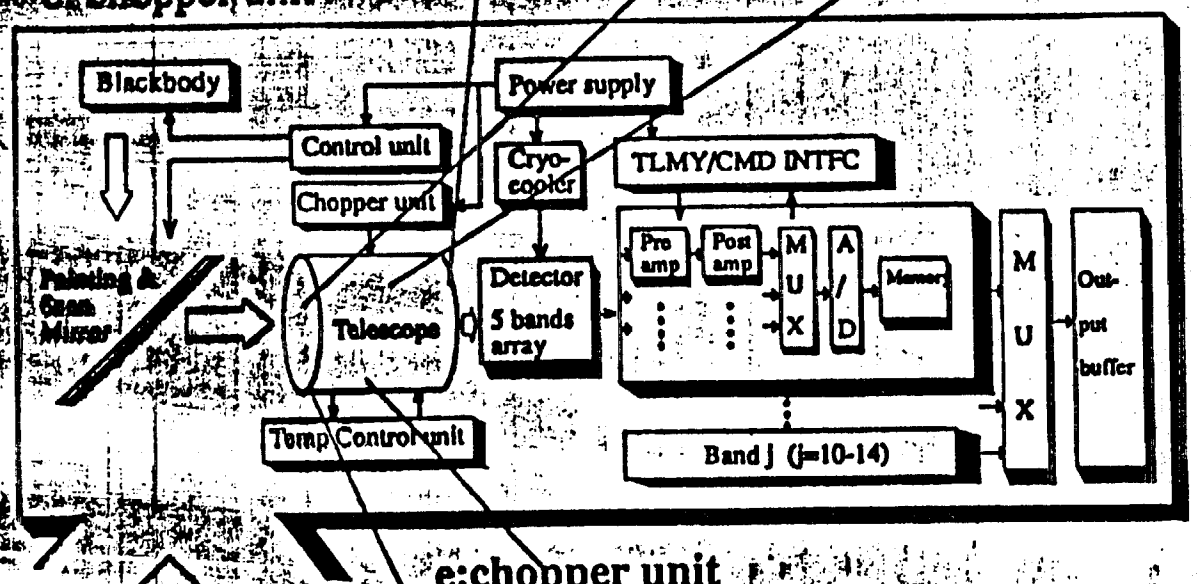
a: primary mirror

b: secondary mirror

c: telescope barrel

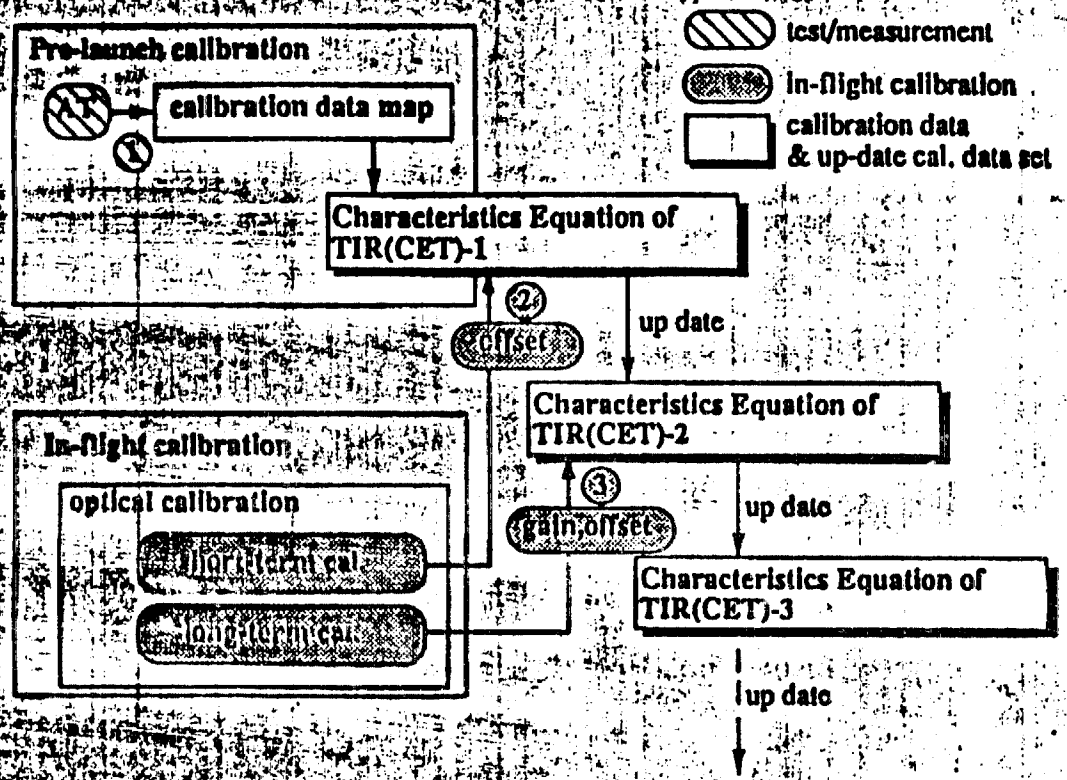
d: lens holder

e: chopper unit



Calibration methods

Calibration data management



Calibration methods

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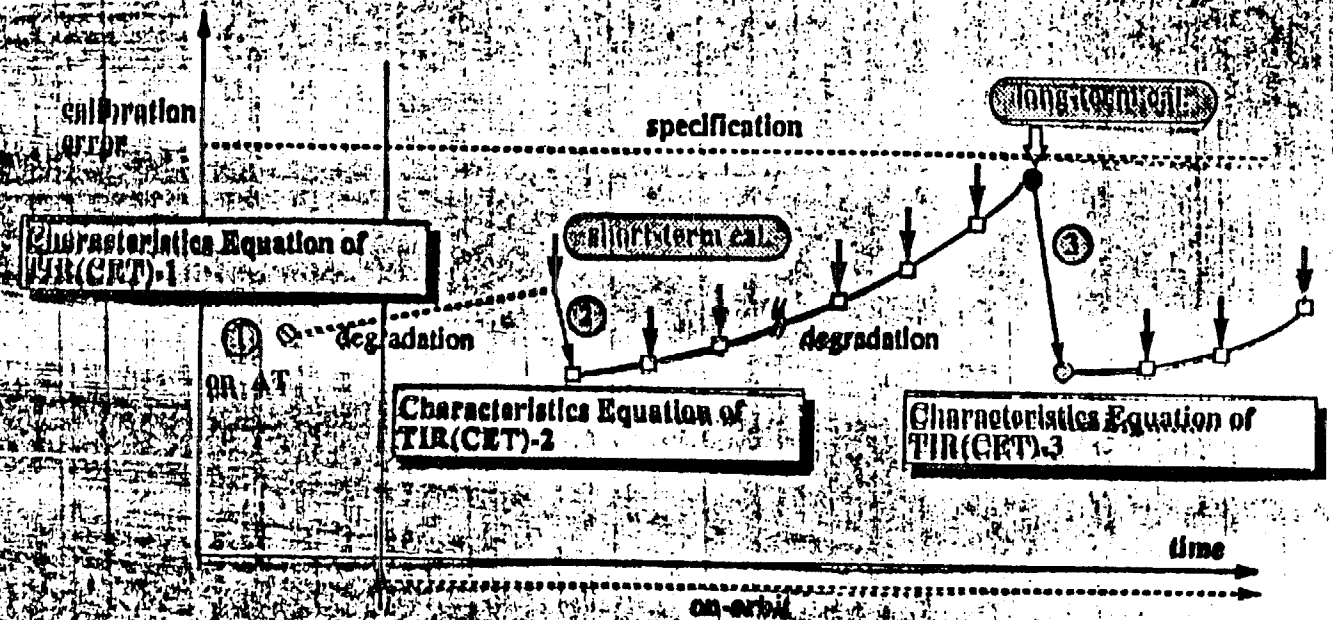
Calibration data management



TIR calibration concept

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Calibration methods

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Summary of calibration methods

stage		usable data	calibration
Pre-launch calibration		calibration data map	- remove the fixed error - determine the characteristics equation
In-flight calibration	short-term calibration mode	- image data :1-temperature radiation - monitor data	- update of the data map ---> improve offset
	long-term calibration mode	- image data :3- or more temperature radiation - monitor data	- update of the data map ---> improve offset and gain and the characteristics equation

Mathematical model

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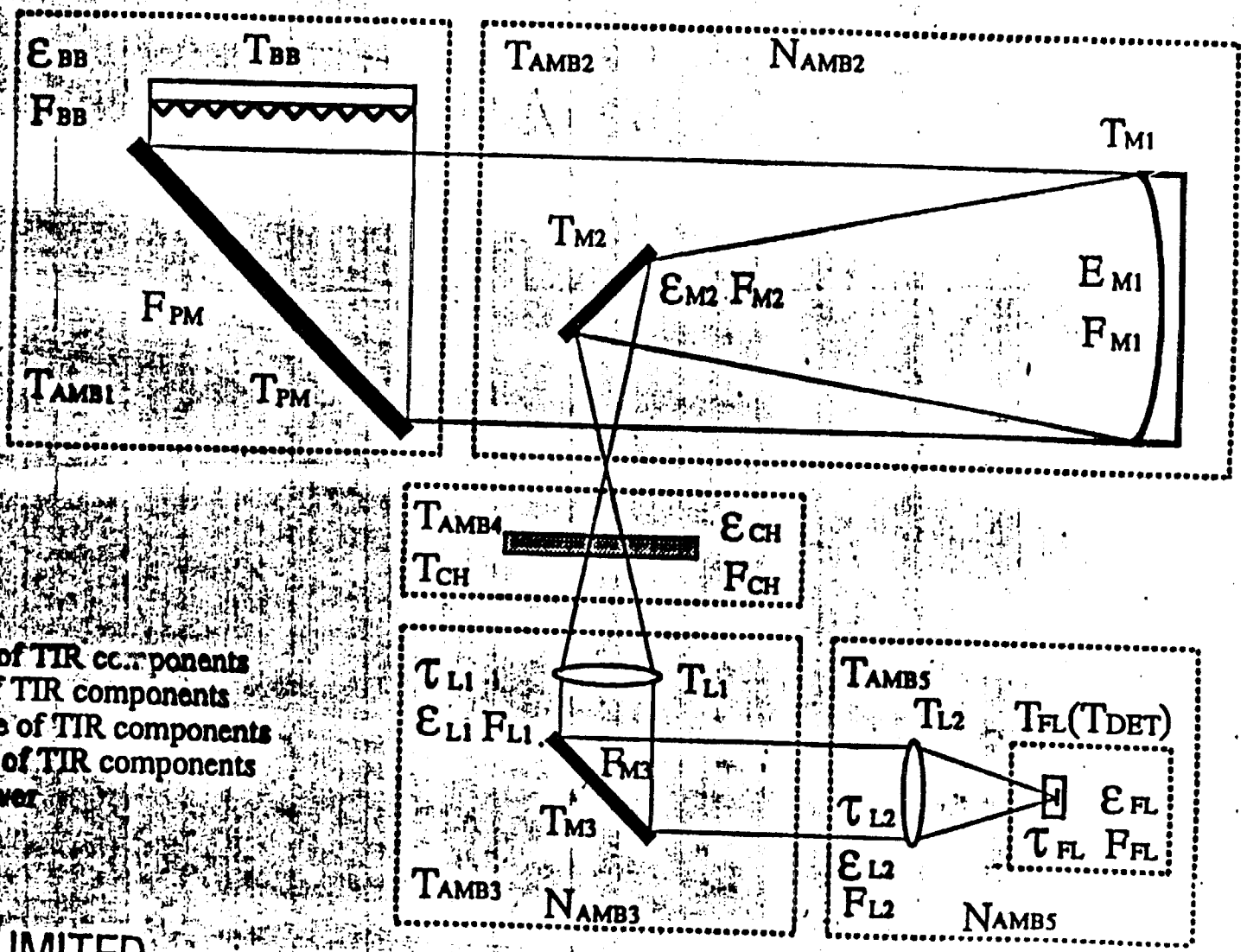
Outline of mathematical model



Ti :temperature of TIR components
εi :emissivity of TIR components
τi :transmittance of TIR components
Fi :shape factor of TIR components
N :radiation power

Mathematical model

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Value of mathematical parameter

stage	critical parameters		comments
	items	value for model	
Pre-launch calibration	emissivity accuracy of standard blackbody	ε=0.995 $\Delta\varepsilon$=0.005	
In-flight calibration	emissivity degradation of on-board blackbody	BOL=0.990 EOL=0.980	degradation test by using test piece

Error Budget for TIR Temperature Scale Calibration

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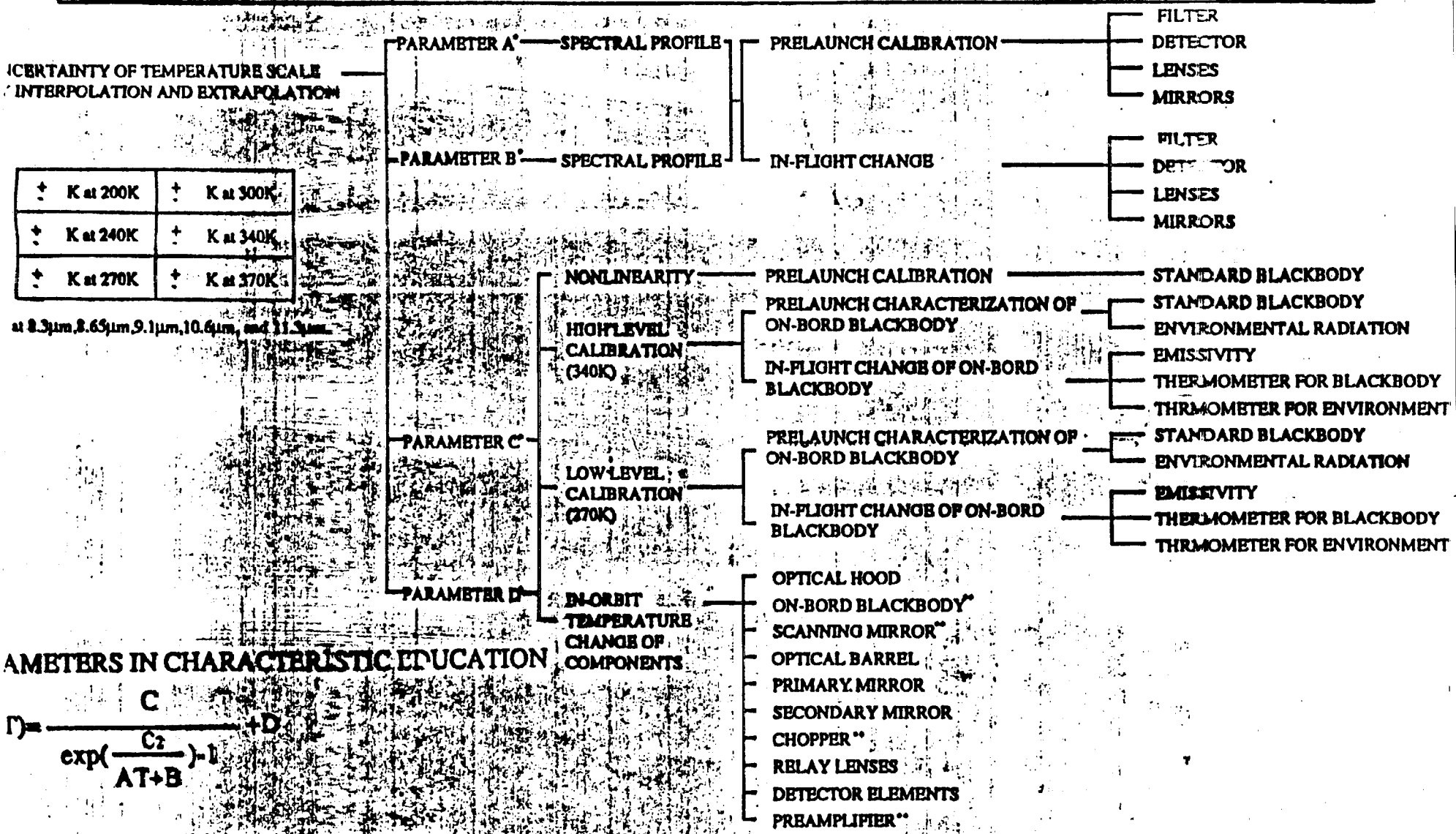

Error Budget for TIR Temperature Scale Calibration

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UNCERTAINTY OF TEMPERATURE SCALE BY INTERPOLATION AND EXTRAPOLATION

DISTRIBUTED VALUE

ACCURACY

± 2.9 K at 200K	± 0.26 K at 300K
± 0.79 K at 240K	± 0.26 K at 340K
± 0.27 K at 270K	± 0.43 K at 370K

at 8.3μm,8.65μm,9.1μm,10.6μm, and 11.3μm.

- PARAMETER A* — SPECTRAL PROFILE
- PARAMETER B* — SPECTRAL PROFILE
- PARAMETER C*
  - NONLINEARITY — (T.B.D.)
  - HIGH LEVEL CALIBRATION (340K) 0.20K
  - LOW LEVEL CALIBRATION (270K) 0.22K
- PARAMETER D*
  - IN-ORBIT TEMPERATURE CHANGE COMPONENTS 0.17K

* PARAMETERS IN CHARACTERISTIC EDUCATION

$$V(T)=\frac{C}{\exp\left(\frac{C_2}{AT+B}\right)-1}+D$$

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Cross-calibration

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Application of cross calibration data

- Cross calibration is very effective method for validation of observation data
- Some requirements for TIR are shown as follows:
  - temperature range for cross calibration : 200K-370K
  - the minimum size of the cross calibration blackbody :
    - larger than 400 mm for full aperture which include pointing and scanning.
    - 330mm-diameter for just scanning

Cross-calibration

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Kendall radiometer

- NASA/GSFC recommends to use the Kendall radiometer for round robin measurements of the instrument manufacture's standard blackbodies.
  Kendall radiometer includes the radiometer and measuring system.
- Our comments for using Kendall radiometer are as follows:
  - It is better to use Kendall radiometer with the standard blackbody togather with a transfer blackbody
  - Kendall radiometer needs to fit configuration of the instrument manufacture's standard blackbody
  - standard blackbody specifications and conditions for TIR as follows:
    - size :larger than 13-inch X 15-inch plate
    - surface figure :Hexaprismatic surface
    - temperature range:100-400K
    - setting position :just in front of TIR aperture with hood
- We need Kendall radiometer in EM and PFM phase